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WATERWAYS DIVISION

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CANAL AND LOCKS AT CHAIN OF ROCKS, MISSISSIPPI RIVER

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The Mississippi River has been an important artery of commerce since the pioneer days of this country. The river in its natural state presented many problems to navigators, and sandbars, snags, rapids, jutting rocks, shifting channels, and fluctuating stages all contributed to the difficulties encountered. Improvement of the river in the interest of navigation is of long standing, and as of today much has been accomplished through various means to provide the navigator with an established, dependable water highway.

The Port of St. Louis, situated as it is immediately below the mouth of Missouri River and but 38 miles below the mouth of Illinois River, was for many years the practical head of substantial navigation. The improvement of the upper Mississippi from the mouth of the Missouri to St. Paul and Minneapolis by means of a series of 26 locks and dams plus some channel deepening, widening, and straightening, together with canalization of the Illinois River from its mouth to Lake Michigan at Chicago, Ill., has provided these areas upstream of St. Louis with a practical, dependable means of water transportation, and, as of today, the tonnages carried on the Mississippi above St. Louis and between St. Louis and the mouth of the Ohio River are approximately equal. The growth of traffic, 11,000,000 tons in 1950 as compared to 3,500,000 tons in 1940, is an indication of the extent to which the waterway is being used.

The Eads Bridge crosses the Mississippi River at St. Louis, 180 miles above the mouth of the Ohio at Cairo, Illinois. The Missouri enters the Mississippi at mile 195; the locks and dam at Alton, Ill., the lowermost of the 26 navigation structures on the upper Mississippi, are at mile 203; the Illinois River joins the Mississippi at mile 218; and Minneapolis, Minn., is at mile 853. These few mileages, together with Plate 1, are given to provide the reader with a simple yardstick and to invite attention to the location of the subject of this paper.

The Chain of Rocks reach lies between mile 184, near the upstream limits of St. Louis, and the mouth of Missouri River. Because of rock ledges at several locations within this reach, high velocities at low and high river stages, narrow channel at low water, and shallow depths during times of low stream flow (less than 6 feet at extreme low flows), this reach has long been known as a serious obstacle to a more complete use of the river. Interested persons, from time to time, obtained congressional authority for investigation of this troublesome reach, and in March of 1945 Congress authorized improvement by means of a bypass canal and locks.

The over-all plan (Plate 2) consists of an upper canal leaving the river at mile 194, just below the mouth of the Missouri, the locks located about 6-1/2 miles downstream, and a lower canal, slightly more than one mile long,

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entering the Mississippi at mile 184, all designed to afford a channel compatible with that provided in the open and canalized sections of the river. The improvement, about 8 miles long, provides a bypass two miles shorter than the natural river.

The upper canal was obtained by excavating a channel with bottom width of 300 feet at elevation 378 and one on three side slopes and depositing the material in levees paralleling the canal on each side (see Plate 3). At elevation 398 a water-surface width of 420 feet is available. The levee along the left or east bank is also a link in the flood-protection works for East St. Louis and vicinity. Excavation and embankment were accomplished by a combination of dry-land and floating-plant methods, top soil being deposited in toe levees by dragline; the main levee fill, largely sandy soil, being placed by hydraulic dredge, and dry-land methods again in use for additional lifts of toe levees and for final shaping and placement of top soil. Revetment, consisting of a blanket of slag (specific gravity about 3.4) averaging 12 inches in thickness and 65 feet wide, measured along the slopes, is being placed on both banks of the channel throughout the length of the canal to provide against wave wash. The lower canal is similar in section to the upper, its bottom elevation being 362, with levee heights at comparable elevations.

The canal entrances have been and still are under careful consideration. The upper entrance, immediately below the mouth of the Missouri River, is so placed and shaped as to provide good entrance conditions for tows operating on the Missouri and Mississippi channels. Silt, particularly from the Missouri River, is an important factor. To help solve this problem, model tests were run at the Waterways Laboratory at Vicksburg, Miss. These tests, together with studies of aerial photographs, indicated clearly that the canal, with entrance located in the bend of the river, at about mile 194, would be fed by Mississippi River water following the bend. The silt content of the upper Mississippi is but 20% of that of the Missouri. Silt deposits are to be expected in the canal, but, due to the comparatively slack water, they are expected to be confined largely to the upstream mile. A partial excavation of the lower canal was made preparatory to construction of the locks. Subsequent floods have resulted in a considerable silt deposit in the preliminary channel and formation of a bar at the downstream entrance. The west levee along the lower canal is designed and being constructed to minimize this silting and further model testing at the Waterways Laboratory has indicated that a trailer dike extending some 2400 feet downstream from the end of the west levee with top elevation about 11.5 feet above a low-water stage equivalent to zero stage, St. Louis gauge, can be expected to aid materially in reducing the bar formation. Construction of this trailer dike is 50% complete as of July, 1954.

Surface elevations in the upper and lower canals will, of course, be dependent upon like elevations in the Mississippi at the respective entrances. Based on past records, a stage of 397 or higher can be expected 50% of the time at the upper entrance, while similar stage expectancy at the lower entrance is 388. Extreme low water of record indicates a stage of 388.6 at the upper entrance and 376.8 at the lower, a fall of 11.8 feet, while corresponding extreme high stages—437.5 and 432.5—indicate a fall of but 5 feet. From these figures it is evident that the lift of the proposed locks, under natural river conditions, may be expected to vary from five feet at highest stages to about 12 feet at time of low water, the lift 50% of the time being about 9 feet. As a part of the over-all development of the "Chain of Rocks Reach," a relatively low wicket dam is contemplated in the Mississippi River channel near the St. Louis waterworks, mile 190, to provide a pool affording dependable adequate depths during

low flows to and over the lower sills of the Alton Locks (Lock and Dam No. 26), at mile 203. A pool elevation of 398 is planned, which would result in the upper Chain of Rocks canal being at 398 much of the time, with correspondingly greater lifts at the locks; i.e., 21 feet at extreme low water.

The canals and locks have been designed for use under both existing and contemplated pool conditions.

The alignment of the canal intersects a main highway and some important utilities, for all of which crossings had to be provided. A new steel bridge 2368 feet long carries U. S. Highway 66 high over the canal, the channel span of which affords a horizontal clearance of 350 feet and a vertical clearance above high water comparable to that available on the river. A 54-inch reinforced concrete water intake was relocated well below the new channel, dual lines being provided as an insurance factor in view of difficulty of repair. Other smaller water mains and gas and oil pipe lines, as well as telephone and transmission lines, had to be relocated.

Immediately upstream of the locks and adjacent to a well-developed industrial area, the canal prism has been widened by 400 feet for a length of about 7500 feet to obtain material for the levees and at the same time provide a harbor for general use, for towboat turn-around, and pondage for lockages. The shore of this harbor is being developed by parties interested in water transportation.

The two locks, in parallel, were constructed in the dry within a cofferdam area of 12.6 acres at foundation elevation surrounded by earth embankments composed of material excavated from the lock site. Excavation, some 2,500,000 cubic yards, was accomplished largely by hydraulic dredge, the last few feet of material above the rock floor being removed by dry-land methods subsequent to removal of the dredge from the area. Since the cofferdam would be subject to heads varying from 45 to 80 feet during the construction period, a considerable amount of pumpage was anticipated. A pumping capacity of 48,000 gallons per minute was provided and sheet-pile cut-offs to encircle the area were contemplated. However, inflow experience was such that the cut-offs were found unnecessary, the greatest discharge subsequent to unwatering being 8000 gallons per minute.

Preliminary planning involved a lock of standard size, 600 feet by 110 feet, but experience on the river prior to preparation of detail plans indicated the practical need for a longer lock. The trend has been toward tows 1200 feet in length, carrying 16,000 to 18,000 tons of cargo. The main lock, 1200 feet long by 110 feet wide (see plate No. 4), will afford, in a single lockage, passage for the largest tows navigating the river, while the auxiliary lock is equal in size to the standard main locks at other sites on the Mississippi, the Illinois, and the Ohio. The walls of the main lock are built to elevation 432 and, based on past flood frequencies, this elevation will afford passage at all times except for a few days during extreme floods, at which times the open river can be used. Passage of tows through the locks will be practicable with a two-foot freeboard, or, in other words, in the instant case, with the upper pool at elevation 430, For stages higher than 430, the passage of flood waters through the canal is to be prevented by use of an emergency dam erected across the walls and upper gates of both locks, from levee to levee. The auxiliary lock is planned for supplementary and emergency use during all low and medium stages. Its emergency use at times of high water is non-essential because of the availability of the open-river channel and, in consequence, except for the upper gate bay, which is equal in height to the main-lock walls, the west wall is built only to elevation 403, which elevation will permit lockages for

70% of the time. This west wall is so designed as to permit raising it to 432 should the need develop.

The locks are founded on limestone at approximately elevation 340, some 70 feet below natural adjacent ground surface, the walls of the main lock and the head walls of the auxiliary lock being 92 feet in height. Base widths of the east and west walls are generally 45 feet, varying up to 51 feet. The intermediate wall is 40 feet wide. Both locks are designed to permit complete unwatering for necessary repair and/or inspection during low-water seasons. Bulkheads are provided for installation upstream of upper gates to prevent flow through the canal in case of emergency and to form, together with a similar installation at the lower end of the lock and the lock walls, a cofferdam for unwatering. Upstream bulkheads are placed by derricks based on the lock walls. Downstream bulkheads are placed by floating plant. The longitudinal section of the main lock (plate 4) depicts in phantom the bulkhead locations.

As shown on the longitudinal section, the upper gate sills are at elevation 374, providing slightly more than 14-foot depth at extreme low water. The lower gate sills, at elevation 360, provide a low-water depth of nearly 17 feet, the greater depth being planned as a contingency against a further lowering of the low-water plane in St. Louis harbor. The downstream or lower lock gates are of the mitering type, similar to those provided at other locks and with which navigation interests are generally familiar. They are unusual only because of their size, each leaf for the main lock being 61 feet in length and 72 feet high. They are horizontally framed, operate much like ordinary doors, and weigh about 200 tons per leaf. Similar gates for the auxiliary lock are 43 feet high, each leaf weighing approximately 140 tons.

The upper lock gates are double-leaf, vertical-lift gates, each leaf being operated like a lift bridge yet acting together, as does an ordinary double-hung window. In considering the over-all design of the development, the matter of ice disposal from the long canal above the locks was of considerable moment. It was evident that it would be necessary to pass large quantities of water and ice through the lock chambers to clear the canal and to minimize formation of ice, and, since it is impracticable to operate miter gates against an appreciable head of water, another type of gate, one that can be operated to pass flows, had to be provided. Submergible roller and tainter gates were investigated but were found impracticable because of the excessive height of the gate. Sector gates, which open horizontally like miter gates, yet can be operated against a head of water, were also investigated but were eliminated because of the excessive horizontal space needed for gate recesses, they would not be entirely suitable for passage of ice, and because of an unfavorable economic comparison with the type of gate chosen. The elevation of top of wall, 432, the upper sill at 374 (a difference of 58 feet), and that of rock foundation some 30 feet below the sill, together with the considerations stated above, were the determining factors in selection of the double-lift gate, the downstream or operating leaf to be provided with a suitable crest for passing flows to a depth of 10 feet while the upstream leaf in reality forms a movable sill. Each leaf consists of a series of horizontal steel girders supporting the vertical skin plate; is 30 feet high and 115 feet in length to span the 110-foot lock. The operating or downstream leaf weighs about 280 tons and the upstream leaf 170 tons. Each leaf contains buoyancy chambers which, together with counterweights, compensate for 100% of the gate load. They are electrically operated by gate machines and synchronizing motors located in the lock walls at each end of each leaf. The operating gate, capable of being raised and lowered under head, is to be used not only to hold upper

pool and to pass ice, but also to pass flows over it to aid in filling the lock chamber. Its crest is a hinged section which, when raised, acts as a component of the portable high-water dam to prevent flow through the locks. For lowering and raising the gate leaves, a speed of one foot per minute is planned for filling operations, while a speed of 12 feet per minute is available for ordinary gate movement. Immediately downstream of these upper gates a light-weight service-lift bridge, 10 feet in width, is located for access to and from the lock walls and, by means of projecting platforms, for servicing the operating (downstream) leaf of the gate. Like the lift gates, these bridges will be submerged for passage of boats and tows. All gates, miter and lift, were designed for welded construction using structural-grade carbon steel with a basic working stress of 18,000 psi.

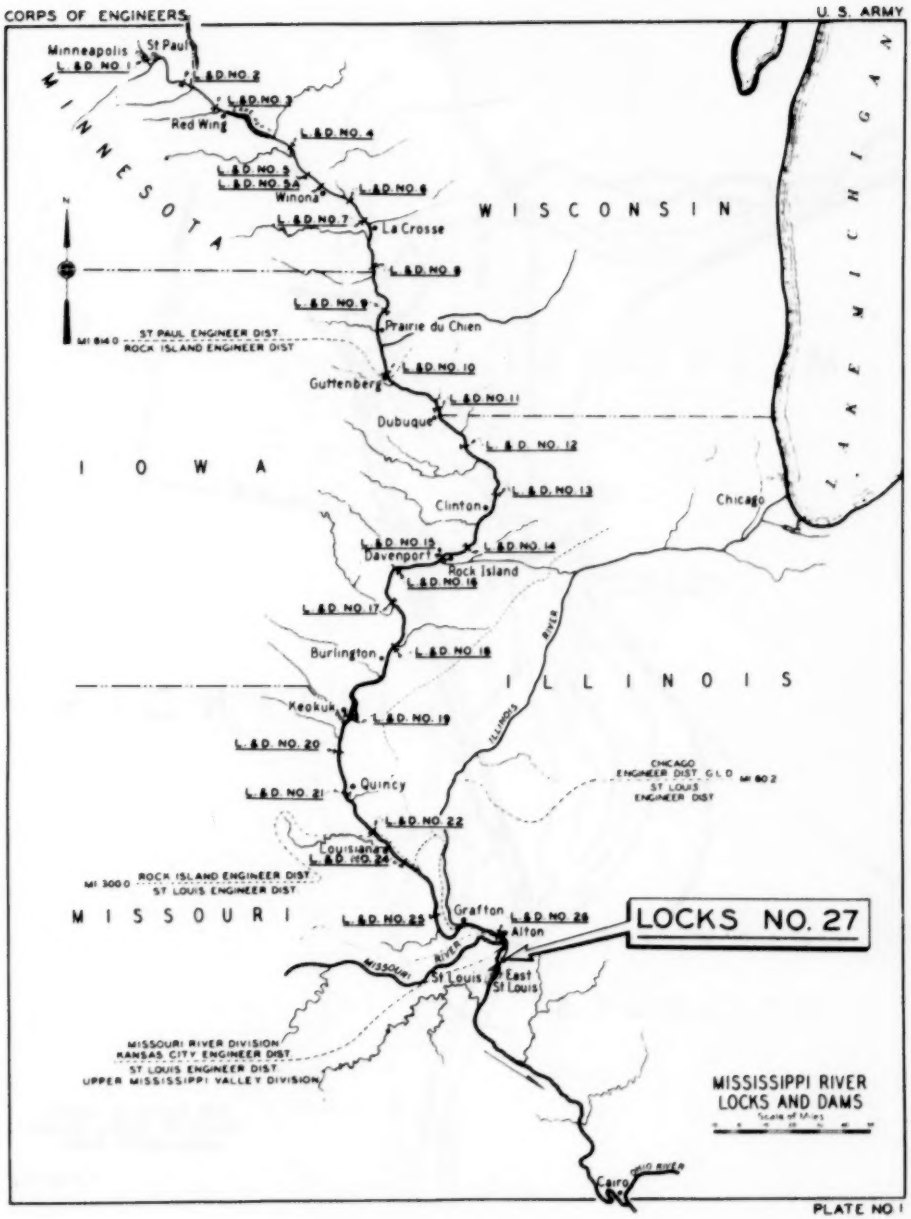
As in most locks, the filling and emptying system required special consideration. The quantity of water per lockage for the same lift for the 1200-foot lock, about 2,900,000 cubic feet for a 21-foot lift, is practically double that for standard 600-foot locks, yet it was desired to find a practical way to hold the time of filling and emptying to about the same time as required for the 600-foot locks. It was also important to limit the flow velocity in both the upper and lower canals resulting from lockage operations, to obtain as little turbulence within the lock chamber and at the point of discharge into the lower approach as practicable, and to limit the mooring-line pull. To arrive at the best answers to these problems a model of the 1200-foot lock and its approaches was constructed in the Hydraulic Laboratory at Iowa University, where the Corps of Engineers, in cooperation with the University, operated and maintained a laboratory and pertinent staff during the period of canalization of the upper Mississippi. To better distribute inflow over the full width of the upper canal, two separate intakes, one across the upper entrance of each lock and located in the bed of the canal upstream of, adjacent to, and with the same top elevation as the upper gate sills, admit flow for filling the 1200-foot lock. The bed or sill type of intake was chosen because of economy. The inflow of water (see Plate No. 4) passes from the intake structures to 14 x 15.5-ft. culverts, one each contained in the base and extending practically the full length of each lock wall, from which ports (2' 6" x 3' 0") connect with the lock chamber just above the surface of bed rock. Even with the lower pool at extreme low water these filling ports will be submerged about 25 feet. This submergence, made practicable by the elevation of the rock foundation, together with the spacing of the ports so that the jets from opposite walls will not impinge on each other, as determined by model tests, results in exceedingly quiet conditions within the lock chamber during filling operations.

The flow of water into and out of the 1200-foot lock is controlled by five tainter valves, two filling and three emptying. They are all equal in size; i.e., 12.5 x 15.5 feet, and are operated by electrically motivated valve machines. The lock will fill, with a difference in upper and lower pool of 21 feet, the maximum lift, in about nine minutes. However, the filling may be hastened by supplementing the flow through the culverts with flow over the vertical-lift upper lock gate. The proper timing and synchronizing of these flows were determined in the laboratory and it is planned to hold the combined inflow to a peak of about 10,000 c.f.s., the filling time for the maximum lift being cut to 7-1/2 minutes. Under maximum inflow-outflow conditions, average velocities in upper and lower approach channels of 1-1/2 and 2-1/2 ft./sec., respectively, are indicated. Culvert bulkheads are provided for use upstream and downstream of all valves to permit unwatering for necessary repairs or replacements.

As previously indicated, two filling valves and three emptying valves have been provided. The third emptying valve is required to expedite the discharge from the chamber, supplementing the usual dual means of discharge as the flow over the upper gate supplements the inflow and resulting in emptying time equivalent to that of filling; i.e., 7-1/2 minutes for a 21-foot difference in pool elevation. Model tests indicated too much turbulence below the lower gates for the usual port discharge; i.e., direct discharge from side ports. In consequence, diffusers were developed to dissipate the energy. There are three sets of these diffusers, one being controlled by each of the emptying valves. To obtain practically even distribution of flow from the large lock over the entire width of the lower canal, the discharge from the land-wall culvert empties immediately below the lower lock gates, that from one valve in the intermediate wall through its diffuser into the lower approach of the auxiliary lock, while that flow from the second or downstream discharge valve in the intermediate wall discharges equally below each lock.

The auxiliary lock is filled by means of a single intake adjacent to its upper sill, a culvert in its land wall, and a system of diffusers in the bed of the lock chamber. The diffuser is used in this instance to minimize the adverse effects of filling from one side only. The lock discharges through a single diffuser system located immediately below the lower gates.

Other than the improvements under way at the lower canal entrance (July, 1954), the entire project is completed and was opened to traffic in February, 1953, said traffic as of above date amounting to over 1,000,000 tons per month.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Minneapolis
St Paul
L & D NO 1
L & D NO 2
L & D NO 3
Red Wing
L & D NO 4
L & D NO 5
L & D NO 5A
Winona
L & D NO 6
L & D NO 7
La Crosse
MINNESOTA
WISCONSIN
LAKE MICHIGAN
L & D NO 8
L & D NO 9
Prairie du Chien
MI 840.0
ST PAUL ENGINEER DIST
ROCK ISLAND ENGINEER DIST
L & D NO 10
Guttenberg
L & D NO 11
Dubuque
L & D NO 12
IOWA
L & D NO 13
Clinton
Chicago
L & D NO 15
L & D NO 14
Davenport
Rock Island
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Burlington
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ILLINOIS
Keokuk
L & D NO 19
L & D NO 20
Quincy
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ST LOUIS ENGINEER DIST
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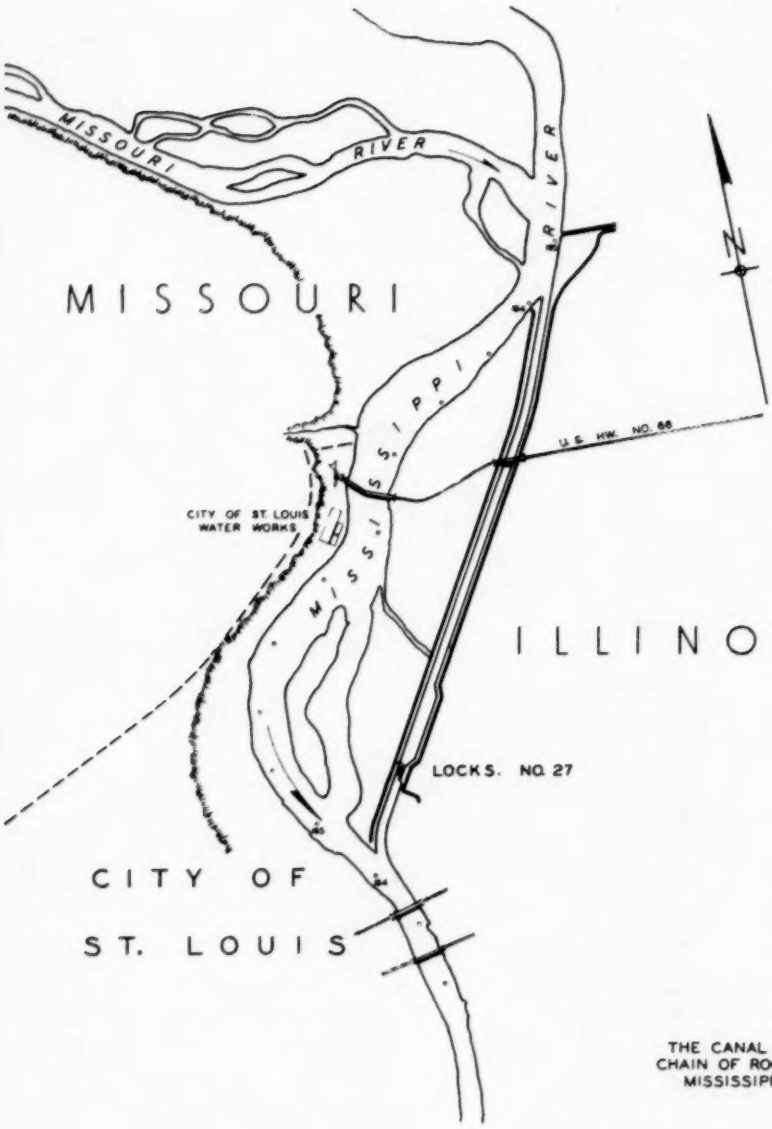
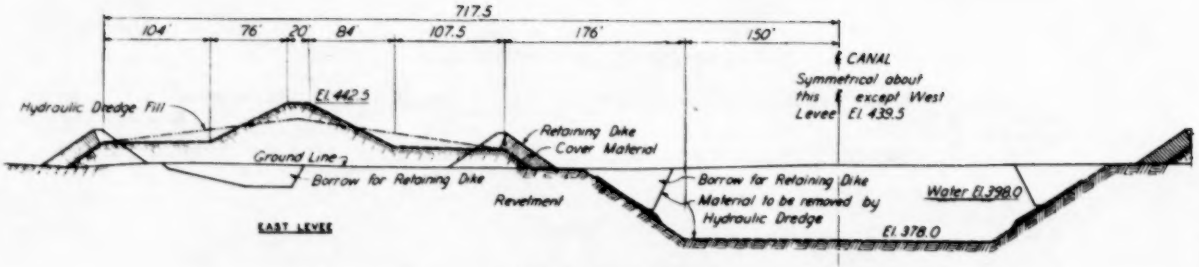
ST LOUIS ENGINEER DIST
MISSOURI
L & D NO 25
Grafton
L & D NO 26
Alton
LOCKS NO. 27
Missouri River
St Louis
East St Louis
MISSOURI RIVER DIVISION
KANSAS CITY ENGINEER DIST
ST LOUIS ENGINEER DIST
UPPER MISSISSIPPI VALLEY DIVISION
MISSISSIPPI RIVER
LOCKS AND DAMS
Scale of Miles
Cairo
Ohio River
PLATE NO 1



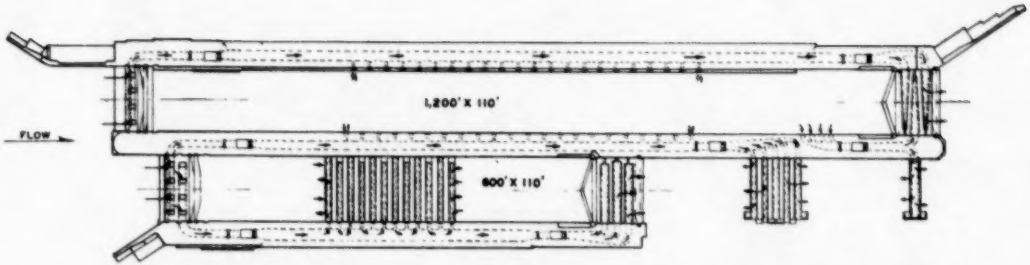
THE CANAL & LOCKS
CHAIN OF ROCKS REACH
MISSISSIPPI RIVER

PLATE NO. 2



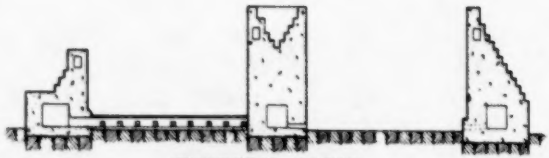
TYPICAL SECTION THROUGH CANAL
LOOKING DOWN STREAM

PLATE NO. 3



PLAN

LONGITUDIAL SECTION ON CENTERLINE (1,200' LOCK)



TRANSVERSE SECTION
LOOKING UP STREAM

PLATE NO. 4